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Waste to energy status in India: A short review

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A R T I C L E I N F O

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A B S T R A C T

India is one of the most rapidly developing countries in the world. It is witnessing growing industrialization and thus development. Such rapid development needs energy to progress, which further makes India an energy hungry nation. Currently India depends mainly upon fossil fuels and thus has to pay a huge bill at the end of every contractual period. These bills can be shortened and the expenditures brought down by using and exploiting non-conventional sources of energy. India holds a huge potential for such non-conventional sources of energy.

The rapid development of India is not just pressing hard upon its resources but forcing expenditures on the same. There are also some neglected side effects of this development process like, generation of waste. A population of 1.2 billion is generating 0.5 kg per person every day. This, sums up to a huge pile of waste, which is mostly landfilled in the most unhygienic manner possible. Such unmanaged waste not only eats up resources but demands expenditure as well. This can lead to the downfall of an economy and degradation of the nation.

Thus, the paper presents waste to energy as a solution to both the problems stated above, using which not only can we reduce the amount of waste, but also produce energy from the same, thus achieving our goal of waste management as well as energy security. The paper presents the current status, major achievements and future aspects of waste to energy in India which will help decision makers, planners and bodies involved in the management of municipal solid waste understand the current status challenges and barriers of MSWM in India for further better planning and management.

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1. Introduction

India, the 11th largest economy in the world in terms of Gross Domestic Product (GDP) and the 3rd largest economy in the world in terms of Purchasing Power Parity (PPP), is a fast developing nation [1]. It is witnessing a boom in industrialization, urbanization and population which is putting a surmounting pressure on the nation's resources and generating a burgeoning amount of waste. The same is the case with all the remaining developing or developed nations like Malaysia, Nepal, Bangladesh, etc. [2]. India, the second most populous country in the world with a population of 1.2 billion, has witnessed a population growth of 31.8% during the last decade [3].

The rapid increase in population witnessed by the country puts a strong declining thrust on the nation's resources. Thus, it is expected that the nation works towards optimum utilization of resources as well as recovering whatever one could out of the utilized resources. This will create a path towards attaining sustainability in terms of resource utilization. The 3Rs (Reduce, Reuse and Recycle) should be kept in mind while working towards resource utilization.

On the contrary if optimum resource utilization is not supervised upon, it can lead to an increase in waste, pollution and a downfall in the economy. Not only can it downgrade the economy, but also take a toll on the environment and the health of the citizens through harmful emissions. Thus it is of utmost importance to keep a constant eye on the utilization and recovery of resources.

The uncontrolled urbanization in India has not allowed the town and cities to cope up. They lack basic amenities like a proper sewage system, drainage system, solid waste management system, etc. [2]. Changing lifestyles and fashion over the years has led to a huge change in the amount of waste generated [4]. This has led to an increased burden on the government, local authorities and the urban local bodies (ULB) to manage the collection, processing and disposal of waste [5]. The most common practice of managing waste today is landfilling, which poses a huge threat to the environment in the form of green-house gases (GHG) leakage in the form of CO_2 and CH_4 and leachate production. Thus this technique needs to be improved [6].

Thus, there is an urgent need to come up with an environmentally, economically and socially sustainable solid waste management process. Waste to energy is one such process that has long been neglected, but holds strong potential to derive energy from the unused resource, i.e., waste.

2. Worldwide status of waste to energy (WTE)

The concept of waste to energy has developed since a while now. The developed countries have started implementing it successfully as measure of waste management as well as energy security. Increasing development leads to a change in lifestyles and status, leading to a burgeoning amount of waste generation. Thus, many countries have taken a step forward and started recovering energy from garbage.

Let us have a historical glance at the usage of waste to energy techniques. In USA in 1990, an estimated 394 trillion Btu of energy was consumed, produced from MSW. According to Japanese Ministry of Health and Welfare (MHW), electricity generation was in operation at 102 waste incineration plants as of late 1991. Many waste-to-energy plants were operational in Germany in the 90's. Cleaner fuels and modern incineration technology resulted in 90% reduction in Swedish incineration plant emissions since 1985. In United Kingdom, the 70th report by the Royal Commission on Environmental Pollution very precisely stated the importance of modern technology in the field of waste to energy [7].

With such developments in the 90's, today waste to energy techniques have attained much modernization as well as importance. It has also diversified in terms of the feedstock it uses. Let us have a look at the current practices of waste to energy, globally.

Poland uses agricultural biomass to generate electricity. At the end of 2012, there were 29 agricultural biogas plants in Poland with an average installed capacity of 1 MW [8]. Malaysia has also been very active as far as WTE techniques are concerned. Methane emissions from Malaysian landfills for 2010 were equivalent to 2.20×10^9 kWh of electricity and were expected to generate USD 219.5 million. The estimates for 2015 and 2020 are USD 243.63 million and USD 262.79 million respectively [9,10]. Italy has witnessed installation of many anaerobic co-digestion plants ranging between 50 kW and 1 MW [11]. Agricultural biomass has been used as feedstock in many African countries including Ghana to produce decentralized rural energy. The total output they obtain is 12.5 kW electric power using two generators rated 5 kVA and 7.5 kVA. The produced electricity is supplied to the community using a local grid of 230 V for 12 h per day [12]. Thessaloniki city of Greece has been following the integrated solid waste management and energy production since a while now using innovations like the use of biocells to better utilize the biogas produced [13]. Singapore has been long focusing on the energy recovery option from food waste produced and thus has formulated many policies to promote the same [14]. Canada has also put its foot on the pedal and accelerated the system to convert food waste to energy and has designed various system designs to meet the required standards. Its system design produces 134.6 MWh per year of surplus energy [15].

Thus, the world is moving fast in adapting this technology, which does not just help the nations with waste management, but also with energy security. Thus, the time is ripe for the developing as well as under developed nations to start emulating these nations and take a step forward in the direction of sustainable MSW management practice.

3. Waste generation in India

Changing lifestyles and increasing PPP of urban Indians, has increased the per capita waste generation rate in India from

0.44 kg/day in 2001 to 0.5 kg/day in 2011. This has led to an increase of 50% in the waste generated by Indian cities in a span of a decade since 2001. India has 53 cities with a million plus population, which together account for 86,000 TPD (31.5 million tons per year) of waste generated. The total Municipal Solid Waste (MSW) generated in India is estimated 68.8 MTY or 188,500 TPD [3]. Such an increase in the amount of waste generated has not only laid a burden on the resources of the nation, but has also become a threat to the health, safety and environment of the nation.

4. Types of waste management practices

Waste management practices in India are still in their nascent stage. The waste management practices are not able to cope up with the rate at which the waste is generated. This has attracted the attention of many, and thus, the field of waste management has witnessed many innovations. MSW is a mix of many things as stated below in Table 1

Various types of waste conversion processes are available based on the type, quantity and property of feedstock, the desired form of the energy, end use requirements, economic conditions, environmental standards and project-specific factors [2]. The waste conversion processes commonly in use are thermal conversions (incineration, pyrolysis, gasification, refuse derived fuel (RDF)), bio-chemical conversions (composting, vermicomposting, anaerobic digestion/biomethanation) and chemical conversions (transesterification and other processes to convert plant and vegetable oils to biodiesel) [2,3]. Each one of them has their corresponding advantages and limitations. This section gives a briefing on the most common and the upcoming ones.

4.1. Thermal conversions

Incineration, pyrolysis and gasification techniques are included in thermal conversions of waste. They result in the production of various byproducts which can be subjected to various energy and resource recovery techniques for treatment.

4.1.1. Incineration

Incineration is one of the most common waste treatment techniques in India owing to its ability to reduce waste mass by 70% and volume by up to 90%. In the process, it aids in energy recovery from the waste to generate electricity [2,3].

The process is carried out in three steps, namely, incineration, energy recovery and air pollution control [16]. Emissions from the process contain air pollutants like SO_x, CO_x, and NO_x, which may result in air pollution and health hazards. Thus, it is of prime importance to equip the incinerator with emission control accessories. The process is carried out in a temperature range of 750–1000 °C and can be coupled with steam and electricity generation processes. The process produces an effectively sterile ash residue [2].

Table 1
MSW mix.

Component	Material	Reference
Compostables	Food waste, landscape, tree trimmings, etc.	[3]
Recyclables	Papers, plastics, glasses, metals, etc.	[56,57,43]
Inerts	Stones and silt, inorganic material, etc.	[13]
Toxic substances	Paints, pesticides, used batteries, medicines, etc.	[56,57,43]

4.1.2. Pyrolysis

Pyrolysis is a thermal waste treatment method carried out in an oxygen free environment. Three types of pyrolysis processes exist depending upon their operational parameters, namely, conventional pyrolysis, fast pyrolysis and flash pyrolysis. Table 2 summarizes the operational parameters of these three types.

With the treatment of MSW using the above listed pyrolysis processes, we get pyrolysis gas as the product, the composition of which is given in Table 3.

4.1.3. Gasification

The gasification process constitutes partial combustion of biomass to produce gas and char initially. The product gases, mainly CO_2 and H_2O, are then reduced using charcoal to CO and H_2. Depending upon the reactor design and the operational parameters, the process also generates some methane and other higher hydrocarbons (HC) [17]. Various heterogeneous reactions convert the feedstock to gas in the presence of a gasification agent [18–20]. The combustible gas produced contains CO, CO_2, CH_4, H_2, H_2O, inert gases present in the gasification agent, trace amounts of higher HCs, and various contaminants such as small char particles, tars and ash [21].

If the gasification process does not proceed using oxidizing agent, an external energy source is needed. This gasification process using an external agent is known as Indirect Gasification process [22,23]. The most commonly used indirect gasification agent is steam owing to its ease of production and its ability to increase the hydrogen content of the combustible gas produced [22].

A gasification system comprises three main components: (1) the gasifier, which produces the combustible gas; (2) the clean-up system, which removes the hazardous components of the combustible gas; and (3) the energy recovery system [24].

4.2. Biochemical conversion

Biochemical conversion of waste to energy is much more eco-friendly as compared to the previous techniques discussed. Biochemical conversion primarily consists of converting the waste into energy by the action of enzymes of microorganisms. The techniques falling under this category are Anaerobic Digestion and Composting.

In Anaerobic digestion (AD), organic waste is fed to the process as feedstock, which is acted upon by microorganisms in absence of oxygen [25–29]. This reduces the amount of waste and produces

Table 2
Operating parameters for pyrolysis process.

Parameters	Conventional pyrolysis	Fast pyrolysis	Flash pyrolysis
Temperature (K)	550–900	850–1250	1050–1300
Heating rate (K/s)	0.1–1	10–200	> 1000
Particle size (mm)	5–50	< 1	< 0.2
Residence time (s)	300–3600	0.5–10	< 0.5
Reference	[58,59]	[60,61]	[60,61]

Table 3
Composition of pyrolysis gas from MSW.

Constituent	Amount (vol%)	Reference
CO	35.5	[62]
CO_2	16.4	[62]
CH_4	11.0	[62]
H_2	37.1	[62]
Calorific value (kcal/Nm^3)	3430	[62]

Table 4
Advantages and disadvantages of different MSWM technologies [63].

Technology	Advantages	Disadvantages
Anaerobic digestion	Energy recovery with production of high grade soil conditioner	Unsuitable for wastes containing less organic matter
	No power requirement for sieving and turning of waste pile	Requires waste segregation for improving digestion efficiency
	Enclosed system enables trapping the gas produced for use	
	Controls GHG emissions	
	Free from bad odor, rodent and fly menace, visible pollution and social resistance	
	Compact design needs less land area	
	Net positive environmental gains	
	Can be done in small scale	
Landfill gas recovery	Least cost option	Surface runoff during rainfall causes pollution
	Gas produced can be utilized for power generation or direct thermal application	Soil and groundwater may get polluted by the leachate
	Skilled personnel not required	Yields only 30%–40% of the total gas generated
	Natural resources are returned to the soil and recycled	Large land area required
	Can convert marshy lands to useful areas	Significant transportation costs
		Cost of pre-treatment to upgrade the gas to pipeline quality and leachate treatment may be significant
		Spontaneous explosion due to methane gas build up
Incineration	Most suitable for high calorific value waste	Least suited for aqueous, high moisture content, low calorific value and chlorinated waste
	Units with high throughput and continuous feed can be set up	Toxic metal concentration in ash, particulate emissions, SO_x, NO_x, chlorinated compounds, ranging from HCL to dioxins
	Thermal energy for power generation or direct heating	High capital and O&M costs
	Relatively noiseless and odorless	Skilled personnel required
	Low lands are required	Overall efficiency for small power stations is low
	Can be located within city limits, reducing transportation costs	
	Hygienic	
Pyrolysis/ Gasification	Production of fuel gas/oil, which can be used for various purposes	Net energy recovery may suffer in waste with excessive moisture
	Control of pollution superior as compared to incineration	High viscosity of pyrolysis oil may be problematic for its burning and transportation

biogas which can be utilized for combined heat and power (CHP) or as a transport fuel. The remaining inorganic and the inert waste are either incinerated or gasified. During the process, the temperature may rise as high as 65 °C, but starts to fall within a couple of months [2]. It has been estimated that by controlled AD, 1 t of MSW produces 2–4 times as much methane in 3 weeks in comparison to what 1 t of waste in landfill will produce in 6–7 years [30,31].

United Nations Environment Program (UNEP) defines composting as the biological decomposition of biodegradable solid waste under predominantly aerobic conditions to a state that is sufficiently stable for nuisance-free storage and handling and is satisfactorily matured for safe use in agriculture [3]. Energy released during oxidation is the cause for rise in temperatures during composting. Due to this energy loss, aerobic composting falls below anaerobic composting on the hierarchy of waste management. Composting mixed wastes results in low quality compost, which is less beneficial and has the potential to introduce heavy metals into human food chain [32].

4.3. Landfilling

In India more than 90% of the MSW generated finds its way to the landfill sites, often in the most unhygienic manner possible [33]. The landfilling process of the municipal solid waste management (MSWM) is the most unorganized one, albeit the most used one. The entire process is in omnishambles. In India the meaning of landfilling process has changed to simply dumping the waste in areas outside the city without taking any kind of sanitary measures. This not only pollutes the environment but also poses a severe threat to the health of citizens in the vicinity. In many coastal areas such unsanitary landfilling has led to leaching of heavy metals into the waters.

Growing population has reduced the amount of land available for such activities for e.g., in Delhi [34], [35–38]. The boundaries of the cities are extending and such sites have become a part of the city at many places. No proper leakage preventive measures are observed such as compaction, leveling of waste and final covering by soil. These sites are also devoid of proper leachate collection system and landfill gas monitoring and collection system [39]. As no source segregation is observed in India, the waste that collects at these sites is often unsegregated. Toxic substances lie in common with other wastes. Also in many instances one may find industrial waste lying at sites originally meant for domestic waste [40].

It seems evident that landfilling is going to continue as the primary MSWM technique in the near future, since all the other techniques produce some residue that must be landfilled, and thus, it is advisable to follow the principles of sanitation [41]. Table 4 below summarizes the advantages and the disadvantages of the different technological options.

5. Potential of energy recovery from urban and industrial waste in India

With increasing population, a major challenge that all the developing nations face is that of MSWM of its waste generated. With increasing development the waste generated has made its management unsustainable. Thus, it is of prime importance that general public awareness is spread across the masses regarding maintaining optimum sanitary measures while treating or disposing the waste.

Table 5
State-wise energy recovery potential of MSW in India [42].

State/Union territory	Energy recovery potential (MW)
Andhra Pradesh	107.0
Assam	6.0
Bihar	67.0
Chandigarh	5.0
Chhattisgarh	22.0
Delhi	111.0
Gujarat	98.0
Haryana	18.0
Himachal Pradesh	1.0
Jharkhand	8.0
Karnataka	125.0
Kerala	32.0
Madhya Pradesh	68.0
Maharashtra	250.0
Manipur	1.5
Meghalaya	1.5
Mizoram	1.0
Orissa	19.0
Pondicherry	2.0
Punjab	39.0
Rajasthan	53.0
Tamil Nadu	137.0
Tripura	1.0
Uttar Pradesh	154.0
Uttaranchal	4.0
West Bengal	126.0
Total	**1457.0**

India, the second most populous country in the world with a population of 1.2 billion, generates a huge amount of waste daily (0.5 kg/person/day) [3]. The same waste holds tremendous potential to generate energy. According to Ministry of New and Renewable Energy (MNRE) estimates, there exists a potential of about 1460 MW of energy from MSW [42]. The following table, Table 5 gives a measure of state-wise potential of energy recovery from the MSW generated.

6. Current status of waste to energy techniques in India

India is a developing country and thus produces a huge amount of waste every year. Recovering energy out of the waste produced is a complicated, yet, resourceful method. India has always been lagging in this field owing to reasons namely the lack of policy framework, technological advancements, infrastructure, sustainable planning and insufficient funding sources [43]. Yet, the nation has not stopped trying and is still constantly experimenting to extract energy out of its enormous pile of waste. Let us have a look at the various wastes to energy projects operating throughout the country in a state-wise manner.

6.1. Andhra Pradesh

Andhra Pradesh has an installation of quite a few RDF plants at Hyderabad, Guntur and Vijaywada. The Hyderabad plant was commissioned in 1999 near Golconda dumping ground. It has a capacity of 1000 TPD but received only 700 TPD of waste until in use. It produced around 210 TPD of fluff and pellets, and was also going to generate power of about 6.6 MW. The Vijaywada plant handled 500 TPD of MSW to generate 6 MW of power. Currently none of these plants are in use [44].

6.2. Chandigarh

Chandigarh has witnessed installation of a RDF plant with a capacity of 500 TPD of MSW to produce pellets and other solid fuel. But today, the plant is rarely operated and lies dormant, but it is being retrofitted with MSW drying systems to reduce moisture in the final RDF [3].

6.3. Delhi

The first large scale waste incineration plant was set up at Timarpur, New Delhi in 1987, by Miljotecknik volunteer, Denmark. It has a capacity of 300 t per day and costed INR 250 million. The plant was out of operation within 6 months which forced Municipal Corporation of Delhi to shut it down [45]. The latest development in the same direction is the set up of another incineration plant at Okhla land fill site, New Delhi, which has recently begun its operations. It is designed to generate 16 MW of electricity by combusting 1350 t per day of MSW. Apart from these plants, a great deal of experience lies with Delhi in the field of biomethanation system [28], but it will take a while before this experience can be used to set up large scale projects owing to lack of basic infrastructure, technology and a strong policy framework. In addition, a gasification unit is also installed at Gaul Pahari campus, New Delhi, by The Energy Research Institute (TERI) [46].

6.4. Gujarat

Gujarat is one of the frontrunners in using renewable sources of energy in India. The state has effectively started using waste to energy techniques as well. Anaerobic digestion is used by M/S Kanoria chemicals Ltd., Ankleshwar to generate 2 MW of power. Similarly, M/S Anil Starch Products Ltd., is producing 4800 nm^3 of biogas per day using anaerobic digestion process. A 0.5 MW capacity power plant at sewage treatment plant has been set up at Surat. Many other such small scale plants exist in Gujarat. Apart from biomethanation, RDF is also practiced in Gujarat, with Rajkot leading the progress. A public private partnership of Rajkot Municipal Corporation and Hanjer Biotech Pvt. Ltd. have established a novel MSW management process, which enables them to produce Fluff/Green coal from dry organic waste and Bio-bricks from the inert waste [47,48].

6.5. Karnataka

A RDF project had been established in Bangalore in October 1989, for compacting 50 TPD of garbage into 5 t of fuel pellets, which could be designed for both, domestic as well as industrial uses. Apart from RDF plants Bangalore boasts of good research work on biomethanation projects. Many biomethanation pilot plants are in operation and significant work is carried out to increase the scalability of the biomethanation plants [43].

6.6. Kerela

Biotech, a biogas technology company based in Thiruvananthpuram, has installed 20,000 household biogas units, which divert 2.5% of organic waste from landfill. In the process they save INR 225 million to Thiruvananthpuram and Kochi ULBs in transportation costs every year. These units also aid in avoiding 7000 t of CO_2 equivalent every year [3].

6.7. Madhya Pradesh

The industrial waste treatment plant based on the principle of waste to energy was commissioned at Som Distilleries, Bhopal, on

June 5, 1999. The project produces biogas using a biomethanation digester. Approximately 900 cm^3 of raw spent wash generates 34,000 m of biogas per day. The plant capacity is 2.7 MW and was expected to generate a minimum of 16×10 kWh per annum [2].

6.8. Maharashtra

Maharashtra is one of the frontrunners in taking the initiative to convert waste to energy. Maharashtra Energy Development Agency (MEDA) is constantly inviting potential investors to invest in this process. Thus, they have been successful in implementing many plants and pilot projects in Mumbai, Pune, Nashik, etc. [49]. Western Paques, Pune, has already completed testing biogas production using anaerobic digestion. The results reveal that 150t/day of MSW produces 14,000 m^3 of biogas with methane content of 55%–65%. It has the potential to generate 1.2 MW of power. The government is promoting to make this process a secondary source of energy by utilizing municipal, industrial and agricultural waste [28]. In the same direction Pune Municipal Corporation has taken a step forward to develop a MSW biomethanation plant that serves in managing the waste as well as generates power. With a plant capacity of 1×5 t per day of segregated organic MSW, the process can produce 300 m^3 of biogas per day, resulting into the generation of 375 kW/day of electricity. The plant has been operational since November 2009 [50]. Apart from this, an incineration plant was put up at BARC, Trombay, to burn institutional waste [43]. In addition, one RDF plant at Deonar, Mumbai, owned by Excel India was set up in early 90's to process garbage into pellets. However, the plant is not in operation since a few years now [51]. The landfill site at Gorai, Mumbai had been tapped in 2008 for capturing and flaring landfill gas (LFG) [3].

6.9. Rajasthan

A gasifier unit has been installed at Nohar, Hanungarh by Narvreet Energy Research and Information (NERI) to combust forest wastes, agro-wastes and saw mill dust. With an efficiency of 70%–80%, the waste feeding rate is about 50–150 kg/h. Out of the total fuel gas produced, about 25% is recycled back into the system to support the process, while the remaining fraction is recovered and used for power generation [31]. Apart from this, a RDF plant is installed near Jaipur. It combusts the RDF produced in cement kilns to replace fossil fuels and handles 500 TPD of waste. It is not operated regularly [3].

6.10. Tamil Nadu

The capital city, Chennai, generates around 2500 t of MSW per day. Two international companies and two national companies are competing amongst each other as well as with the state owned company, Tamilnadu Agro Engineering Federation, for government approval for managing the MSW [2]. A 15 MW waste to energy project has been established by an Australian company, namely, Energy Development Ltd., financed by State bank of India (SBI) and Canara Bank [52].

6.11. Uttar Pradesh

Uttar Pradesh has been one of the pioneering states in the field of waste to energy, albeit it was greeted with failure. One of the first large scale anaerobic digestion plants was set up in Lucknow, to generate 6 MW of electricity, but failed due to the lack of source separation. The Nonconventional Energy Development Agency (NEDA), Department of Additional Sources of Energy, Government of Uttar Pradesh, has invited potential investors to tap their waste generated and generate energy [49].

6.12. West Bengal

According to a study conducted by [53], waste to energy does not appear to be feasible as a waste reduction process, at either large scale or small scale. Thus, currently waste to energy process is not considered as a MSW management and reduction process [53]. The major problem in MSW management at West Bengal is due to lack of waste segregation at source, low percentage of house to house collection, large number of open vats, low operational efficiency of waste transport system with old vehicles, low collection efficiency in newly added areas and an inefficient informal recycling system. Though, the state of west Bengal has witnessed the above mentioned challenge, it has never shut its doors to the initiatives to ensure improvements. After repeated experimentation and research, West Bengal is looking forward to attract investors in this field.

According to MNRE out of the 1460 MW of power available, India is able to tap and exploit only 24 MW. This is just 1.64% of the total potential. Let us have a look at the current waste to energy installed capacity in India, represented by Table 6.

7. Failure

India is a developing country and thus is witnessing a rapid rise in the amount of waste it generates every day, month and year. India has tried quite a few things until now to extract energy from the waste generated, but has often met with failures. Ten aerobic composting projects in 1970s, a WTE project in 1980s, a large scale biomethanation project, and two RDF projects in 2003, have all met with failure. Large scale biomethanation has failed owing to the absence of source separation. A major plant in Lucknow to produce 6 MW of electricity failed due to this reason. However the same process has shown huge success on small scale, using kitchen waste, market waste, restaurant waste, etc. India has a total of 5 RDF processing plants, all of which have encountered operational problems due to lack of proper financial and logistical planning and not due to technology. 2 RDF plants have already been shut down [3].

The initial failures of waste to energy technologies have turned people against the technology, which has turned out to be a key barrier in development today. Though the process has attracted the attention of many, it is going to take a while before people change their mindset and respond in a positive manner.

8. Indian MSWM policy

The Ministry of Environment and Forests (MoEF) of the Government of India has issued the MSW rules in the year 2000 for scientific

Table 6
Current waste to energy installed capacity [55].

Grid Interactive Power	Capacities (MW)	Contribution (%)
Waste to Power		
Urban	20.20	27.4
Industrial	53.46	72.6
Total	73.66	
Off grid/Captive power	**Capacities (MW Eq)**	**Contribution (%)**
Waste to Energy		
Urban	3.50	4.6
Industrial	72.30	95.4
Total	75.80	

MSWM, ensuring proper collection, separation, transportation, processing and disposal of MSW and upgradation of the existing facilities to curb soil and groundwater contamination. Central Pollution Control Board (CPCB) acts as the watchdog, and is the authority to which the municipalities are supposed to submit their annual reports. Additionally, there are Municipal Corporation Acts issued by the states themselves, which further deal with the environmental degradation caused by improper MSWM techniques. Most of the municipalities are unable to provide the desired level of services due to a number of problems [37,38,54,35].

MNRE has always promoted innovations in field of waste to energy in form of training, financial assistance, etc. The following is a list of points which enlists the various financial incentives and other eligibility criteria as proposed by MNRE for participation in waste to energy projects [55].

- Financial assistance is provided by way of interest subsidy for commercial projects.
- Financial assistance is provided on the capital cost for demonstration projects that are innovative in terms of generation of power from municipal/ industrial wastes.
- Financial assistance is provided for power generation in STPs.
- Financial incentives are given to municipal corporations for supplying garbage free of cost at the project site and for providing land.
- Incentives are given to the state nodal agencies for promotion, co-ordination and monitoring of such projects.
- Financial assistance is given for carrying out studies on waste to energy projects, covering full costs of such studies.
- Assistance is given in terms of training courses, workshops and seminars and awareness generation.

9. Conclusion

Waste to energy process has been long tried at various Indian cities, but has generally met with failures. The main causes behind these failures are lack of financial and logistical planning and absence of a strong policy framework for waste to energy process. A number of initial failures over the decades have turned the citizens as well as investors against the process.

But the mindsets are changing with increasing development and education. Also, the increasing prices of fuel and power have made such waste to energy projects much more viable. Thus, many investments in the form pilot as well as large scale plants have been witnessed throughout the nation.

Further few key suggestive highlights of the current study are,

1. There is a need for micro or locality base plans which can provide details as to routes, timing, equipment and manpower deployment for achieving a high level target collection, transportation, treatment and disposal.
2. Primary collection i.e. door to door collection and segregation at house hold level on regular basis may give a new lease of life to the existing MSWM system in India.
3. Proper source segregation of wastes.
4. Increasing participation ratio of civil society in the MSWM through conducting capacity building programe and awareness campaign. The ultimate aim of this movement should find a way to educate the masses and spread awareness to the citizens about the hazardous effects of improper MSWM and the benefits of proper & hygienic MSWM.
5. The informal policy of encouraging the public to separate MSW and market it directly to the informal network appears to be better option.
6. Encourage and promote private participation in MSWM and Involvement of people and private sector through NGOs could improve the efficiency of MSWM.
7. Proper infrastructural facilities and training to street sweepers.
8. Proper infrastructural development for collection of wastes at public places such as bus stand, taxi stand, market places etc.
9. Technical up-gradation and capacity improvement of existing disposal sites.
10. In future an on-line management information system needs to be effectively implemented to optimize daily operating resources allotment and make the Indian solid waste management system effective and sustainable.
11. Bridge the gap between policy and their implementation with proper MSWM system.

Hence in totality it can be summarized that there is a need for integrated waste management system coupled with reduction in waste load. Further the energy potential of MSW can play an important role for the nation in ensuring sustainable development and attaining energy security.

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